THE USE AND CARE OF REFLECTING TELESCOPES.

By W. F. Hoyt, Kansas Wesleyan University, Salina.

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IN the precision of its adjustments, in the wealth of mechanical details, in the number and intrinsic value of its attachments, the modern telescope is the prince among human instruments. There are two main kinds of telescopes, each with its fundamental advantages and disadvantages. The power of an instrument is determined largely by its light-gathering ability. Since the surface of a lens varies as the square of its diameter, the greater the aperture, other things being equal, the better the telescope. The refractor excels the reflector somewhat in light-gathering efficiency, because a lens intercepts less light than is lost by two reflections, as is necessary in modern reflectors. The small diagonal mirror, too, intercepts a considerable percentage of the light before it reaches the large speculum. The definition of refracting telescopes is usually superior, owing to slight possible distortion of mirrors, or to the unevenness of the silver coating. Refracting telescopes are but slightly affected by time or usage, while reflectors are tarnished after a few years, and must be repolished or resilvered, or both. On the other hand, a good reflector is absolutely achromatic, while chromatic aberration is inevitable in the best refractors. The aberration of the violet and other actinic rays in refractors render them undesirable for photographic work, for which reflectors are especially adapted. Owing to this, every well-equipped observatory has one or more reflectors as general working instruments. It was the two-foot reflector in the Yerkes observatory, for instance, instead of the great forty-inch refractor, that made the famous discoveries concerning Nova Persei recently. Mr. Schaeberle, of Ann Arbor, Mich., has constructed a large reflector with only an eighteen-inch focus, with which he claims to have performed marvels of photography, securing in a few seconds images of faint objects which have heretofore required hours of exposure.

We have probably reached the limit of size in refractors, but if we may believe Mr. Ritchie, of the Yerkes observatory, we have not begun to develop the possibilities of the reflector. He not only claims that a ten-foot reflector is possible, but he offers to construct one if funds are secured. Such an instrument would extend the area of the visible universe a thousand fold. Cheapness of construction and ease of management, however, are prime arguments in favor of reflecting telescopes. A good modern reflector, of twelve-inch aperture, mounted

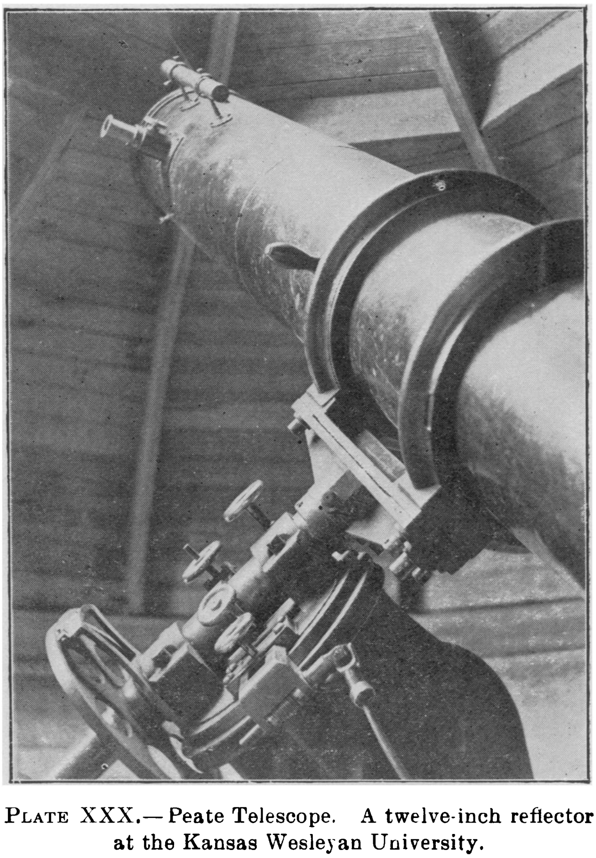

PLATE XXX.— Peate Telescope. A twelve-inch reflector at the Kansas Wesleyan University.

in the usual equatorial style, with right ascension and declination circles and adjusting rods, but without a driving clock and other costly attachments, can be secured for about $500. Such an instrument would bear, with ease, powers ranging from 100 to 500 diameters—a range ample for all practical purposes. When freshly resilvered, this glass would bear a power of 1000. The mounting of such an instrument in a neat observatory need not cost more than $500, and might be brought within $250. The total cost, therefore, need not be more than $750 to $1000. This is not beyond the reach of any moderately thriving educational institution; and yet how few of them have anything approaching such an equipment? Indeed, not longer ago than three years, there was not a single such instrument in the state, and but few telescopes of even moderate pretensions.

The care of such a telescope is not beyond the person of average ability and training. The glass should, of course, be protected by a dust-proof covering of oilcloth or tarpaulin, and, in addition, the open end and eyepiece tube should be securely capped. If carefully protected in this manner, it would be advisable to let the telescope rest in a vertical position, so that the mirror may lie flat, thus avoiding unnecessary strain in the intervals of usage.

A tarnished mirror may sometimes be brightened by rubbing it lightly with a soft chamois skin padded with cotton. A good silver surface can be repolished several times. Sometimes a little rouge upon the pad will aid in polishing. If this does not suffice, the mirror must be resilvered. If the glass is sent away, resilvering and repolishing a twelve-inch mirror will cost about ten dollars, and proportionately for other sizes. If the work is done in the home laboratory, the materials need not cost over fifty cents, and the whole operation can be completed in a half-day. It is better to have the reagents prepared before beginning with the mirror. The directions given below are for a twelve-inch glass, following the process given by Doctor Brashear, of Allegheny, Pa.

Reducing Solution (prepare at least a week before using; the solution improves with age): $2\frac{1}{4}$ oz. white sugar or rock candy; $\frac{1}{20}$ oz. nitric acid; $3\frac{1}{4}$ oz. alcohol; 19 oz. distilled water. Mix, and keep in a well-stoppered bottle. This solution will be sufficient for several operations.

DIRECTIONS FOR SILVERING A TWELVE-INCH MIRROR.

Reagents: $\frac{3}{10}$ oz. potassium hydroxide, dissolved in about 13 oz. distilled water; $\frac{6}{10}$ oz. silver nitrate, dissolved in 13 oz. distilled water (reserve about one-sixth of the silver nitrate for later use); a half pint of dilute (about 25 per cent.) ammonia; a bottle of dilute nitric acid. Too much care cannot be taken to have pure reagents. The

potassium hydroxide should be "pure by alcohol," the ammonia dilute, and the distilled water clean as well as chemically pure. A little caution here may save trouble later.

The mirror may now be cleaned. A little nitric acid poured upon the face of the speculum may be directed to all portions of the glass by tipping it carefully this way and that. This will quickly clear the surface of the tarnished silver. A little more acid should be used to completely dispose of materials that may be dissolved by acid. Potassium hydroxide may now be used (not that mentioned above, which is reserved for silvering) and distributed as was the nitric acid. Further washing may be performed with clean water, and, last of all, with distilled water. This should be continued till the surface of the glass when dried looks clear by light reflected at an acute angle. Avoid touching the surface of the mirror if possible. If, however, the surface cannot otherwise be cleaned, it may be lightly and carefully wiped with a perfectly clean, soft towel, moved in circular and spiral strokes. The glass should be washed again two or three times after such wiping. When perfectly clean, the mirror should be put aside till ready to silver. This may be done by placing it face down in clean water, being careful to keep the surface from contact with hard objects. A better way is to wrap the mirror tightly with paraffined paper, letting the paper project three or four inches above the surface to be silvered. If this is well done, the papered basin, with the mirror at the bottom, should be water-tight. Pour enough distilled water to cover the surface of the glass and lay a paper or towel over the paper edges to keep out the dust. The mirror can be silvered face up in this condition, or face down in a large vessel, if preferred.

Pour the remaining silver-nitrate solution, after making the reserve, into a clean vessel, such as a wash-bowl. Add, drop by drop, the dilute ammonia, stirring briskly all the time with a glass rod. The silver solution will soon change to a light brown color, and finally begin to clear up again. As soon as it shows signs of clearing, stop adding the ammonia and stir a moment. Now pour in the potassium hydroxide. The mixture will now have a muddy brown color. Again drop in carefully and slowly the ammonia, stirring vigorously.

When it begins to clear up again, stop dropping in ammonia and stir briskly. *Beware of excess of ammonia.* Sometimes there are floating particles that refuse to dissolve, but this does not matter if the liquid is clear. Now pour in slowly the reserve silver nitrate, stirring continuously. Just when the liquid changes to a light brown or straw color, add a few drops more to avoid excess of ammonia. If, after stirring two or three minutes, the solution does not

clear up, it is ready for the filter. If the solution clears, however, more of the reserve silver must be added, as it is useless to attempt to silver with an excess of ammonia.

In filtering, a little cotton may be placed in the funnel instead of filter-paper, which is slower and no more efficient than the cotton. Having filtered into the vessel for final mixing, pour in about three and one-half ounces of the reducing solution and wait a few moments until it begins to turn a dark or black color. Meanwhile, pour into the paraffined mirror-vessel as much distilled water as is thought necessary to cover the surface the required depth. About a pint and a half to a quart is sufficient. Pour in the silvering solution, and move the glass near the edge of the table, where it may be tipped this way and that, to keep the sediment of the silvering solution from settling upon the surface, and thus interfering with the silvering. Within five or six minutes the silver will begin to deposit, and in from ten to fifteen minutes the process will be complete. If the ammonia has not been in excess, the coat should be so thick as not to admit the light when held before a window. If left in too long, the coat may receive a tarnish that will be difficult to polish away. If the process has been completely successful, this coating will be thick and brilliant.

Pour the solution into a vessel and throw away, or precipitate as a harmless chloride by adding common salt. A dangerous explosive may form from this mixture, especially if the solutions be too warm. A temperature of about 60 or 65 deg. F. is best for solutions and vessels, as the silver will not deposit well if too cold.

Cut the cords binding the paraffined paper and wash the sediment carefully from the silvered surface with clean water. The surplus water may be allowed to drain away. The drying process may be hastened by absorbing the moisture from the silver by carefully applying clean blotting paper, being careful not to slide the paper. After ten or fifteen minutes the surface should be ready to polish, but the operator must be certain no moisture remains. Three or four pads of the softest and smoothest chamois skin should be at hand, stuffed lightly with cotton. Taking one of these in the hand, rub lightly at first, in spiral strokes over the surface, gradually increasing the firmness of the pressure. This polishing is simply to clear away the loose foreign substances remaining from the washing, and to give a firmness to the silver surface. It should, however, give a fairly good mirror surface from this rubbing. For the final polishing rub into another pad a little polishing rouge, brushing off the surplus rouge. Now go over the surface with the rouged pad until a brilliant surface is obtained. As long as the silver coating remains it will not injure

the glass to polish, but care must be taken not to rub any exposed surface.

The diagonal or some small glass surface should be silvered before the large mirror to test the purity and efficiency of the silvering mixtures. The diagonal may be silvered face down in any vessel not too small to receive it. Care should be taken in this not to immerse the mirror until the bubbles·have disappeared, and the glass should be held in a slanting position to prevent the lodgment of stray bubbles or floating sediment on the surface.

COLLIMATION.

The mounting and collimation of the mirrors is not difficult, with proper caution. An assistant is necessary for this, and indeed very convenient.

After a tentative fastening of the mirrors, the operator should take his place before the eye tube, at a distance of several inches from it, and, by working the adjustment screws, get the center of the speculum, which may be previously marked by a little disk of white paper pasted on the silvered surface of the large glass, to coincide with the center of the diagonal glass, when that mirror is placed so as to show the same length of the supporting wires on each side. A few minutes will usually suffice for this. Care should be taken not to have any undue pressure upon any part of the speculum. A test of this is that the glass should lie loosely in position. Pressure upon any part will result in an annoying flare of a star image, or even a double image. Since this glass lies free in its place, it is better to manipulate the telescope so as to have the large mirror always at the lower part of the tube.

While these directions may sound formidable to the amateur, they are really simple and easily followed, and the result should be a renewed telescope, ready for satisfactory work. A good test of accurate collimation is to let an astronomical object travel across the field of view and if the definition is equally good in all positions, the mirrors are properly set.